PSYCHE.

PNEUMATIC FUNCTIONS OF INSECTS.

BY GEORGE MACLOSKIE, PRINCETON, N. J.

When handling the larva of a dragon-fly (*Libellula*) which had lain in a solution of caustic potash, I found that squeezing the thorax protruded the proboscis. On removing the pressure, the proboscis folded itself by its elasticity, and returned to its mask-like condition of rest. The experiment could be repeated indefinitely, just as we extend and retract a pair of lazy-tongs. The muscles having been destroyed in these specimens, the movements were purely mechanical, depending on air-pressure and the elasticity of the chitinous membranes. In the fresh specimens similar pressure of the thorax (and in less degree pressure of the abdomen) both protrudes the proboscis and swells its base with air. A cushion in the flexor-side of the angle of the proboscis is much inflated, and on pricking it with a needle it collapses and the power of protrusion is almost destroyed. The proboscis has at its tip muscles for abducting and adducting the terminal lobes relatively to each other; near the base it has a few muscles for guiding and aiding its movements. It is richly supplied with tracheae, and thus is in direct communication with the pneumatic system of the head and thorax. It is surprising that neither Réaumur, nor Léon Dufour, nor the other investigators who made this larva a subject of special study, detected its mode of protruding the proboscis, a matter of easy observation.

The pneumatic function here observed is like that which I have formerly described in the house-fly,[1] and which has been since confirmed by Dimmock.[2] Other instances of the same class have since come to our knowledge.

Gegenbaur ascribes to the abdomen of these larvae a "branchial movement concurring with a natatory movement."[3] Packard speaks of a "hydrostatic" function in the larva of *Corydalis*.[4] Réaumur watched the backward flow of water from the anus of the larvae of libellulids, and stated that it aids in propelling the animal (a view which has been repeated by others; but the main organs of propulsion are the nimble limbs). Dufour admired the structure of their pneumatic branchiae as the most beautiful objects he had ever observed, giving a good account of the mechanism for working them,[5] but he stopped short of what seems to me the most interesting part.

In the thorax are six tracheal trunks, of which the two dorsal ones are exceedingly large, and with few branches save at their anterior and posterior extremities; two others are smaller, line the alimentary tract, and supply it with many branches; the remaining two are very small and

[1] Amer. Naturalist, March 1880, v. 14, p. 157.

[2] The anatomy of the mouth-parts . . . of some diptera. Dissertation . . . Leipzig University. Boston, Williams, 1881.

[3] Manuel d'anat. comparée, Paris, 1874, § 138.

[4] Amer. naturalist, Sept. 1874, v. 8, p. 533.

[5] Ann. des sci. nat., zool., 1852, v. 17, p. 65–100.

adjoin the ventral nerve-cord. The large pair (which we may call the *pneumatic tracheal trunks*) suddenly gives out a crowd of branches in the abdomen, which subdivide again and again, breaking up into a spray of fine filaments which supply the branchial organs.

The branchiae consist of a dozen longitudinal columns around the rectum, each bearing about thirty-five pairs of oval branchial leaflets, pinnately arranged and imbricating over each other. Each leaflet receives about two hundred very delicate filaments from the tracheal branchlets; the filaments are attenuated towards their extremity and end caecally in the sac-like leaflet. Dufour found (in *Aeschna*) that the leaflets are enclosed in pockets or involutions of the intestinal wall; in *Libellula* they seem to lie loosely in the rectal cavity.

The larva respires by drawing in through the anus a gentle flow of water, which it then expels with force, driving the exhausted water and contained impurities to a safe distance. The inflow and outflow may occur about fifty times per minute; and occasionally the process will stop for a while, especially when the larva is at rest. There are sphincter valves at the anus and muscles for regulating the opening and closing of the anal lobes and armature, and a ganglionic enlargement to supply this. But there are no large muscles about the branchiae and no large ganglia in the abdomen to suggest special muscular action. The muscles which line the abdominal wall regulate the respiration. By relaxing they permit the abdomen to expand, causing a partial vacuum: then the water flows gently in, and the air flows from the pneumatic tracheal trunks into the many thousands of filaments which crowd the branchial leaflets. This action may be aided by pressure in the front part of the body which drives the air to the rear; and the pneumatic pressure in the tracheae swells the delicate filaments and the enclosing branchial leaflets simultaneously with the incoming tide of water. The fine membrane permits the passage of gases, but not of the water. The contraction of the abdominal muscles by reducing the vacuum expels both air and water from the branchial region, driving the air forward to the tracheal system. In a specimen imprisoned with water in a glass tube we found that four air-bubbles were expelled with the outgoing tide of water in as many minutes (a result of excitement). Thus the mechanical principle is nearly the same as in lung-respiration. The simultaneous inflow of air and of a fluid follows the expansion of the body-wall, and the contraction of the wall induces a reciprocal outflow. In the insect the fluid comes from without, the air from within; in the air-breathing vertebrate the air comes from without, and the fluid (blood) from the system, being aided in its progress by the heart.[6] Cutting through the abdominal wall of the larva has the same effect as piercing the human pleura, causing the respiratory organs to collapse and stopping their function. If we prevent the expansion of the abdomen of the larva, breathing is temporarily arrested.

M. Jousset de Bellesme[7] discovered that the larval dragon-fly swells out into its adult form by a process which is a kind

[6] Foster's Physiology, 1880, 4th edit., book 2, chap. 2, § 7.

[7] Harper's Annual rec. of sci. . . . 1878, p. 447.

of pneumatic efflation. The pressure of air from within gives definite form to the body; puffs up the forehead into soft bladder-like bumps, and swells out the wings like soap-bubbles, until the two sides come together and harden into the fine wing-membrane with its double plate and enclosed tracheae. This shows the insect's wing to be merely an outgrowth (exodeme) of its body-wall like the pleura of a lobster.

The scale-like larva of the beetle *Psephenus* (once described as a crustacean, *Fluvicola*) which abounds on the loose rocks in our streams, has brush-like tracheal filaments (external to its abdomen) which sweep the water of its oxygen, and may be observed swelling out and "kicking" at every pulsation; a result of pneumatic pressure within the body.

Réaumur observed that young flies can at will inflate a sac on their foreheads, expanding and contracting it. Weismann, in his study of the embryology of diptera, made an observation which seem to me to belong to the same category.[8] The jaws of diptera arise far back in the body, projecting like limbs, before the true limbs show themselves. Subsequently the jaws travel headwards, become directed forwards instead of transversely, and sink out of sight within the oral cavity which is now formed by invagination. Then the head itself is swallowed up in the trunk, being lost to view, and thus we have the well-known headless maggot of these insects. In the subsequent growth of the head-parts this author thinks that there is a complete discontinuity between the larva and the adult, a histolysis or disintegration of the tissues, which must make a new departure in order to continue their growth. Balfour suggests that, instead of a complete break, we may have here only a skipping of intermediate stages. The rule of embryo-life is that when a part has a long journey before it to reach high organization, it starts early, takes all short cuts, and does not delay at the "way-stations." My own observations point to the conclusion that the fine chitinous frame-work and ledges of the introverted head of the larval fly fairly forecast the characteristic structures of the adult, and that the plates of the basi-proboscis occupy in the larva the normal place of an endocranium (with which I deem them homologous).[9] Weismann states that he was unable to trace the development of these parts, because the head was invisible; and hence he could not work out their homologies.

He found, however, that the head came forth to view again from its introverted position by the influence of mechanical pressure. The abdomen contracts, and this drives the contents of the body forwards so as to eject the head. He specifies only the *fluid* contents; but whatever operates on them must *a fortiori* set in motion the pneumatic dynamics of the tracheae which are then distended with air and largely developed towards the head. Hence the whole head is, in the first instance, driven out by the same aerial impulse which subsequently inflates the frontal sac and propels the proboscis.

The same authority states that the fine branches of tracheae in the system terminate in spindle-cells with thin elastic

[8] Zeitschr. f. wiss. Zool., 1863, 1864 and 1866; bd. 13, 14 and 16.

[9] Amer. naturalist, March 1880, v. 14, p. 160.

intima. Is it not possible that tracheal pressure may distend these cells like bladders, and thus facilitate the aeration of the tissues? The conditions for their distention seem to be present at every pulsation, though under dissection they are always collapsed. I have found such terminal enlargements of the tracheae numerously developed in the disti-proboscis of the house-fly. On one occasion I got a fly in a live-cage with the tip of its proboscis pressing the cover-glass; and by focussing the microscope on this, I found that with every pulsation there was a circle of flashing lights along the margin of the proboscis, as if air was rhythmically injected into such sacs. It is easy to understand how such distension would promote the function of the tracheae as carriers of gases between the tissues and the outer world.

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CLUSTER-FLIES.

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At a meeting of the Biological society of Washington, held 13 Oct. 1882, Mr. W: H. Dall exhibited specimens of flies which had been sent him from New York state with an account of their habit of congregating in large numbers in unused apartments of houses, under table-cloths, in pillow-cases, and wherever similar snug places of concealment could be found. These flies were found from late fall until late spring in such situations, but during the summer they disappeared. Specimens were put into the hands of Dr. C: V. Riley, who made a communication upon them at the meeting of the same society, 10 Nov. 1882, dwelling upon the difficulty of identifying the species of the fly and stating that it was the *Pollenia rudis*, described by T. W: Harris as *Musca familiaris*, and making further remarks upon the synonymy. At this meeting Mr. Dall read a letter, received since the presentation of his first communication, from the parties who had sent the specimens, giving a highly colored account of the actions of the flies. Dr. Frank Baker made a more rational statement in regard to the occurrence of flies in Maine, which were probably of the same species, and had similar habits. Dr. Baker stated that as many of the people in Maine still kept up the custom of the home-production of yarns and spun goods, and these goods, of loose texture, retained upon them a considerable quantity of their natural grease, the flies were in the habit of burrowing into such goods, to feed on the grease, and were supposed to cut the fibres. Dr. Riley did not seem to credit the flies with this habit, but there seems to be no reason to doubt the possibility of such injury, and not much improbability about it. The flies were stated to attach themselves sometimes in clusters suspended from ceilings and other supports, and were on this account called "cluster-flies." Mr. Dall's informant stated that the flies were proof, at least to a great extent, against the influence of pyrethrum powder, but Dr. Baker said that if the powder was diffused in an apartment, and the flies were then caused to bestir themselves, and to fly about, they succumbed to the influence of the powder as readily as other flies. Such a difference in observations is not surprising, for it may